CEMENT AND LIME MANUFACTURE

PUBLISHED ALTERNATE MONTHS. PRICE 1/- A COPY. ANNUAL SUBSCRIPTION 6s. POST FREE.

PUBLISHED BY
CONCRETE PUBLICATIONS LIMITED
14 DARTMOUTH STREET, LONDON, S.W.1
TELEPHONE: WHITEHALL 4581.
TELEGRAPHIC ADDRESS:
CONCRETIUS, PARL, LONDON.

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"
"CEMENT & LIME MANUFACTURE"
"THE CONCRETE YEAR BOOK"
"CONCRETE SERIES" BOOKS, ETC.

VOLUME XX. NUMBER 2 MARCH, 1947

The Production of High-Alumina Cement from Waste Products.

DUE to the scarcity of bauxite in Britain during the war, a substitute was found, and used in the manufacture of high-alumina cement, in the form of waste products from the aluminium industry. The following notes describe a plant set up for the use of these substitute materials by the Lafarge Aluminous Cement Co., Ltd.; the drying plant described was supplied by Messrs. Edgar Allen & Co., Ltd.

The waste materials used were bauxite red mud and aluminium dross, both of which were available in large quantities. The process consisted in the preparation of a red mud slurry with which was incorporated a proportion of aluminium dross, the whole being thoroughly agitated and subsequently treated with sulphuric acid. On conclusion of the reaction, the mixture was neutralised by the addition of chalk, and was then diluted and filtered. The filter cake, after being washed and dried, was the material used as an alternative to natural bauxite in the production of high-alumina cement. Both raw materials were delivered by rail and tipped into stock pits served by overhead electric grabbing telphers. A flow-sheet is given in Fig. 1.

The red mud was fed by one of the telphers to the feed hopper of a wash mill, and water was added whilst the mill was running. This mill (Fig. 2) had a 15-ft. diameter tank constructed in reinforced concrete. The slurry from the mill passed through a ⅛-in. square-mesh screen into a sump built out from the periphery of the tank, from which it was pumped to an overhead circular concrete storage tank with a hopper bottom, having a capacity of 1,000 gallons. The slurry was pumped in through the conical bottom of the tank through two 2-way valves, fitted one to the other, the first one having a T port plug and the second an L port plug. The slurry level rose in the tank until the fountain head of a 3-in. overflow pipe was reached, which returned the surplus to the wash mill, thus keeping it in circulation until the correct density was obtained. By means of the T port plug valve the tank could be by-passed and the slurry passed direct from

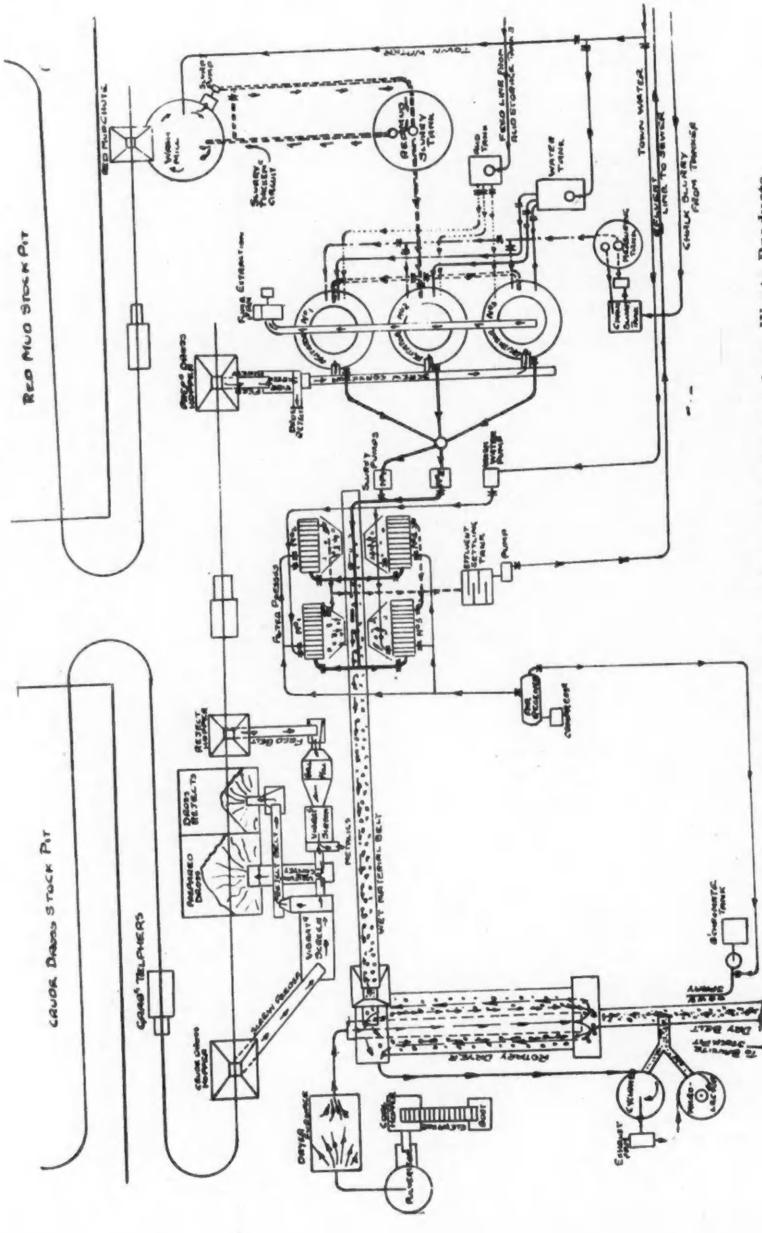

Fig. 1.—Flow-sheet of Plant for Making High-Alumina Cement from Waste Products.

the pump back to the mill, when the pump could be shut down until it was again required. By means of the L port plug valve the slurry could be discharged down a 4-in. pipe into one of three mixers. The aluminium dross was tipped from rail wagons into stock pits adjacent to the red mud. From the pits the dross was fed by the telpher to the hopper of a totally-enclosed screening plant, with a capacity of 20 tons per hour. This hopper, which had a capacity of 3 tons; was fitted with a 3-in. square-mesh screen to retain foreign matter, such as large lumps of aluminium and tramp iron. From this hopper the dross was fed by a 14-in. screw conveyor to a single-deck vibrating screen with a ⅛-in. square-mesh cloth.

The oversize material was discharged on to a 16-in. inclined belt conveyor, fitted with a magnetic separator for removing ferrous materials. The minus

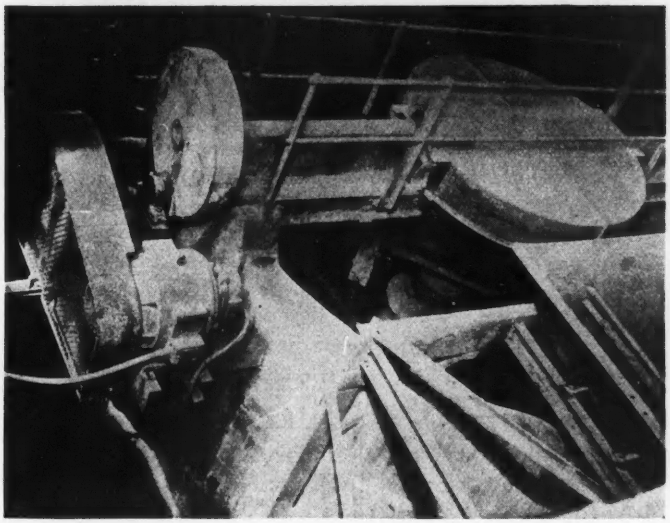

Fig. 2.—Washmill for Red Mud.

⅛-in. material was discharged into a 9-in. uniflow conveyor (Fig. 3) which fed the prepared material stock pile. The rejects from this preliminary screening plant were subjected to further grinding to reduce the dross to minus ⅛ in. and at the same time to separate metallic aluminium, which was valuable scrap. The prepared dross was fed by the grab of the same telpher to the hopper of an automatic weighing plant, which fed the three mixers.

An 8-in. screw feeder conveyed the material from the hopper to a 30-in. by 60-in. vibrating screen fitted with a ⅛-in. square-mesh cloth, the small amount of rejects from which discharged into a skip and was man-handled to the reject pile for subsequent treatment by the ball mill. The minus ⅛-in. material from this screen discharged into a weighing machine, which in turn discharged into an 8-in.

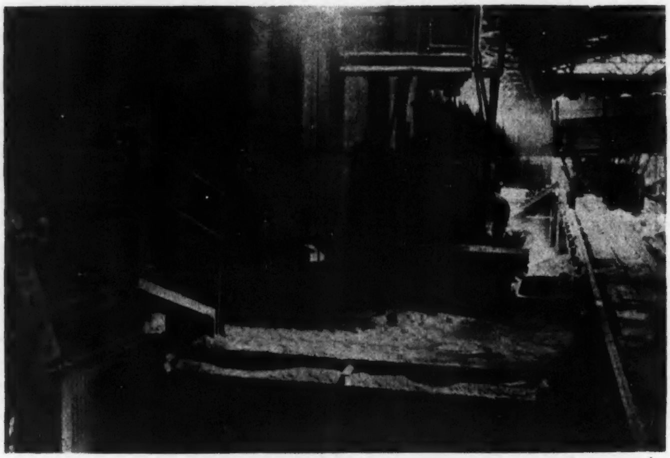

Fig. 3.—Head of Uniflow Conveyor.

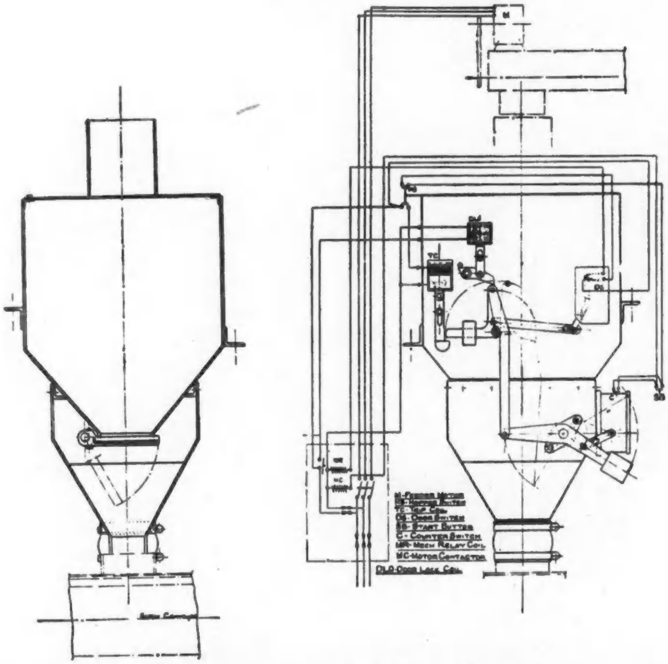

Fig. 4.—Details of Trickle Discharge Hopper.

screw conveyor having a discharge opening at each mixer. The weighing machine was fitted with a trickle discharge hopper of 2½ cwt. capacity. This hopper (Fig. 4), the movement of which controlled the cycle of operations electrically, was rectangular in section, and consisted of one hopper superimposed on another, the bottom one having a discharge opening connected to the screw conveyor below by a canvas seal. The top chamber or hopper had a steel feed-chute directly beneath the discharge chute of the screen and sealed by canvas. It had a discharge opening fitted with a counterbalanced swing door operated by a toggle mechanism. Fitted to the back plate of the hopper was a 0 to 12 single-dial-type counter incorporating a cam-operated micro-switch, the counter spindle being operated by a crank which engaged with an arm mounted on the hopper-door shaft. The micro-switch, which was open-circuited by the cam when the dial read zero, was connected in series with the contactor coil of the starter controlling the screw-feeder motor, a mercury switch actuated by the rise and fall of the weighing hopper and also a door interlock switch, which ensured that the door must be shut tight before a further weighing could commence. Connected across the micro-switch was a push-button which was depressed to make circuit during the first of 12 lb. to 280 lb. weighing, the subsequent 11 weighings being controlled by the micro-switch. The screen and the 8-in. screw conveyor feeding the mixers were run continuously. When the starting button was depressed the feeder commenced to feed the dross through the screen to the weighing hopper, which, when full, fell to its lowest position and stopped the feeder by operating the mercury switch controlling the motor starter. In falling, the hopper operated a second mercury switch, thus energizing a solenoid the plunger of which broke the toggle and opened the door, thus enabling the dross in the top chamber to commence discharging into the bottom hopper from which it was conveyed to the mixers. In this operation the toggle crank passed under a pawl which secured the door in the open position until all the material had been discharged from the top hopper. This took about 70 seconds. At the end of this time an electrically-operated clock set in operation by the opening of the door energized a further solenoid which lifted the toggle-crank pawl and the door was closed by its counterweight. This operation rotated the counter dial from 0 to 1, which completed the feeder-motor circuit and a fresh weighing commenced. The plant continued to work automatically for a further eleven weighings when the counter dial returned to zero, thus open-circuiting the micro-switch and completing the cycle of operations. The object of this arrangement was two-fold. First, to gain time, as the top hopper could quickly discharge itself into the bottom hopper, thus enabling a fresh weighing to commence, while the screw conveyor emptied the bottom hopper at an even rate; secondly, clean operating conditions were obtained when handling an extremely dusty and noxious material, as the entire plant was dust-tight.

Vortex type mixers were used, with a reinforced concrete tank 6 ft. diameter and 10 ft. deep, lined with acid-resisting tiles, sunk flush in the ground. Superimposed over the paddle, but entirely free from it, was a cone under-slung from the bridge by four stay-rods; all these parts being made of acid-resisting bronze.

The combined action of the rotating paddle and the fixed cone can be compared with that of a centrifugal pump having its suction and delivery ports short circuited. The paddle draws the slurry down through the centre of the cone and throws it outwards to the tank wall, which forces it to the surface where it is directed to the centre again by curved fins fitted to the top flange of the cone. Apart from these currents in the vertical plane, there is a swirl or eddy in the horizontal plane, and the combination of the two renders the mixer efficient. Owing to the depth of the tank a steady bearing was necessary for the lower end of the vertical shaft, and considerable trouble was experienced with this bearing owing to the excessive wear in the bearing and on the journal portion of

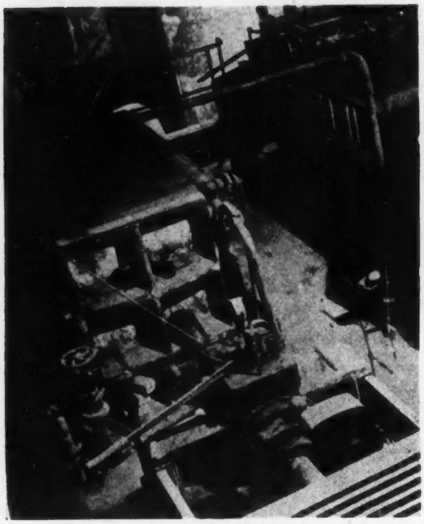

Fig. 5.—Filter Presses.

the shaft due to the aluminium dross content of the slurry, which was extremely abrasive. A successful assembly was developed on the lines characteristic of the diving bell.

When the two raw materials were thoroughly mixed the speed of the revolving paddle was reduced in order to proceed with the acid treatment, for which 75 per cent. concentrated sulphuric acid was required. The acid was stored in lead-lined steel storage tanks situated remote from the plant, and was discharged by gravity by a 2½-in. lead pipe to a float-controlled measuring tank adjacent to the mixer. From the bottom of the measuring tank were three 2½-in. lead pipes, one leading to each mixer and controlled by valves.

Immediately the acid was added to the slurry the ensuing chemical action created dense clouds of fumes which were drawn off by a fume extraction

plant to be discharged through the roof. As soon as the acid reaction was completed, the mixer was again speeded up to maintain agitation, and chalk in the form of slurry was added to neutralise the contents of the mixer. The resultant slurry, although in a fit chemical state for filtering, was too dense to be conveniently handled by the slurry pumps, so it was thinned by the addition of water. The amount of water that could be added to the slurry at this stage was limited, as if the finished slurry was too thin it was unable to hold the total solids in suspen-

Fig. 6.—Arrangement of Dryer and Cyclone.

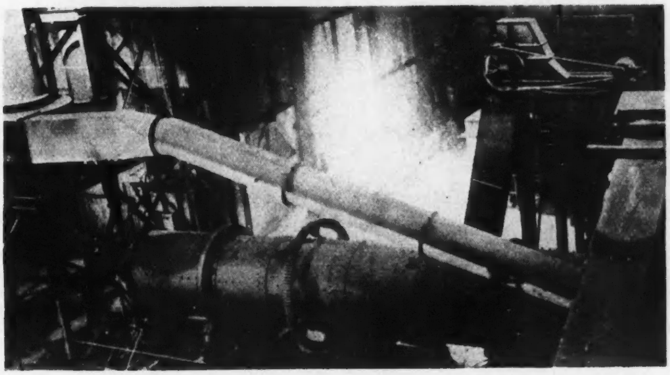

Fig. 7.—Dryer in Foreground : Coal Elevator Hopper in Background.

sion, with the result that the aluminium dross settled and quickly choked the pumps and pipelines which subsequently handled it. Mixing was continued for ten minutes after the final water had been added, when the slurry was pumped into filter presses (F.g. 5), where the solids were retained and the liquid run to waste.

The filter cake was washed by admitting water at a pressure of 100 lb. per square inch. At the commencement of the washing process the effluent produced

had a high specific gravity due to the salts removed from the filter cake and the washing was continued until the specific gravity of the effluent was reduced to such a degree as to indicate that the cake had been cleansed to an economical limit compatible with the quality desired, the whole proceeding taking between twenty and thirty minutes.

The cake was then subjected to a preliminary drying process by admitting compressed air at 80 lb. per square inch, which drove off a good proportion of the free moisture. This process was continued for five to ten minutes, at the end of which time the moisture content of the cake was reduced to about 35 per cent. The press was then opened and the cake discharged down a chute on to a 30-in. troughed belt and conveyed to a rotary dryer (Figs. 6 to 9) having a capacity of 5 tons per hour, which reduced the free moisture content of the cake from 35 per cent. to 12 per cent. The dry material was discharged from the dryer

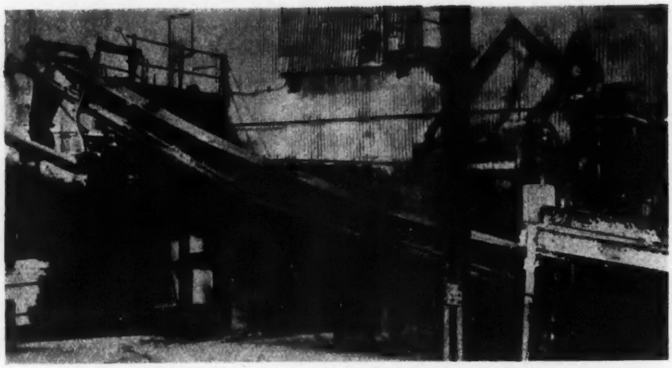

Fig. 8.—Belt-Feeding Wet Material to Dryer : Mill for Rejects in Background.

on to a 20-in. inclined troughed belt, which conveyed it through a spraying tunnel to the stock pile. From here it was handled by a 12-ton overhead grab crane to a briquetting plant which produced ovoid shaped briquettes. These briquettes represented the finished material and replaced the natural lump bauxite.

A spraying tunnel was installed for treating the material from the dryer with sodium bichromate, thus rendering it inert, as otherwise, owing to chemical action on the metallic aluminium particles present, rapid disintegration of the finished briquettes would occur. The sodium bichromate, acting as an inhibitor, prevented this action by providing a protective skin to the metallic particles.

The furnace of the drying plant, which had a combustion space of 8 ft. by 6 ft. by 7 ft., was fired by pulverised coal and worked at a temperature of 900 to 1,000 deg. C., with an average coal consumption of approximately 300 lb. per hour. It was coupled to the inner tube or shell of the dryer by a 2 ft. 6 in. diameter refractory-lined steel flue which entered at the feed end hood of the dryer through a gland.

The dryer was of the double-shell rotary type A.8 size, approximately 5 ft. diameter by 30 ft. long. The inner and outer shells were connected together at the feed end by steel braces, but at all supporting points lower down the shell the braces were screwed and pivoted to allow for the unequal expansion caused by differences of temperature. The dryer was set at an inclination of 1 in 32, and was supported on two steel tyres mounted on the outer shell. The tyres rested on supporting rollers of hard cast iron, and thrust rollers were provided to prevent longitudinal movement. The drive was provided by a heavy gear ring, connected to the outer shell by tangential plates, which engaged a pinion

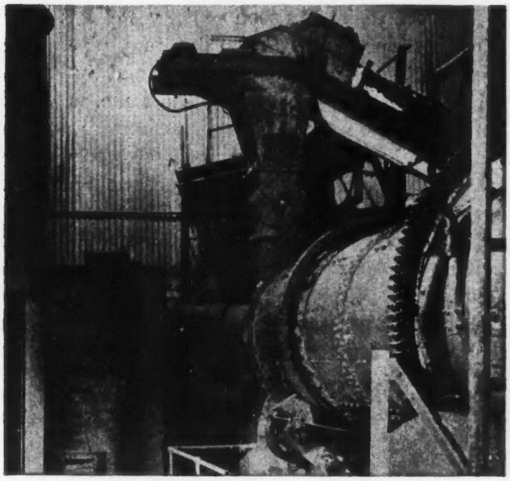

Fig. 9.—Feed End of Rotary Dryer.

keyed to a totally-enclosed worm reduction gear, the high-speed shaft of which was connected to a 15 h.p. electric motor by a vee-rope pulley drive.

The material was fed through the dryer hood into the annular space on the furnace end of the dryer. Lifting flights were provided on the inside of the outer shell, and these lifted the material to the top of the dryer and then dropped it on the hot inner shell, where it was retained for half a revolution by radial flights. This process was repeated continuously, the material gradually working towards the discharge end of the dryer where, just before discharging, it came into contact with the dry gases emitted from the inner shell. The hot gases from the furnace passed through a refractory-lined flue, along the inner shell, then back through the annular space between the two shells in direct contact with the material to the feed hood, where they were drawn off through a dust-extracting plant and discharged to atmosphere. The feed and discharge points of the dryer were provided with motor-driven rotary seals to prevent ingress of cool air to the system.

By means of a spray pipe the bichromate was applied to the synthetic bauxite in the proportion of 0·2 per cent. by weight. The sodium bichromate in dry crystalline form was mixed with water in the proportions of 4 lb. per gallon to form a 40 per cent. solution. The solution was made up in a 300-gallon tank, which fed by gravity a 25-gallon pressure vessel fitted with a gauge glass calibrated in ¼ gallons. The bottom of the pressure vessel was connected to the air-line leading to the spray by a ¼-in. pipe fitted with an adjustable-needle control valve, while connecting the top of the vessel to the airline was a ½-in. pressure equalising pipe. Also in the top of the pressure vessel was an air vent fitted with a valve which was opened to atmosphere when charging the pressure vessel with bichromate from the stock tank. As soon as the vessel was charged the air vent was closed and the air supply turned on to the spray pipe. The needle control valve at the bottom of the vessel was then opened and by virtue of the pressure equalising pipe the pressure in the line was the same as that in the pressure vessel; the bichromate solution flowed into the air stream and was carried away to the spray pipe, through the holes in which it was forced at high velocity and atomised into a fine mist which was readily absorbed by the hot dry material on the belt. As the fumes given off by the bichromate spray were injurious if inhaled, the spray hood worked in a slight vacuum; it was connected to the suction side of the dust extraction plant by an 8-in. diameter pipe controlled by a butterfly valve.

At the conclusion of hostilities the plant was dismantled and dispersed.

A Stoker's Manual.

The Ministry of Fuel and Power has issued an 88-page book entitled "The Stoker's Manual" (London: H.M. Stationery Office. Price 6d.) with the object of increasing boiler efficiency and saving fuel by giving the stoker a greater knowledge of the principles of boiler firing and operation. It is hoped that boiler users will provide each of their stokers with a copy of this manual.

The first part deals with the operation of shell boilers; the methods of firing and the tools used are described, with details of clinker prevention, banking, etc. The meaning of draught, the use of draught gauges, the effect of and prevention of air leakages are discussed at length. There is a section on firing boilers, with particular reference to losses, water level, cleanliness of the boiler-house, blow-down, and smoke. A description of boiler-house instruments is given showing how to make use of the indications given by these instruments. Simple log sheets are illustrated, and diagrammatic pictures show the principal sources of heat loss. A section on mechanical stokers describes the salient features of the principal types of stoker and their operation. In another part, the operation of sectional central-heating boilers is described. Methods of operation and of overhaul, the special features of day and night working, together with drawings of good sets of tools, are included. The last part explains what happens in combustion under various conditions, gives an account of what coal is and of the differences between different types of coal, and deals with excess air and with draught.

Tests on Cement Mortars at the Age of Ten Years.

IN 1931 the United States Bureau of Reclamation inaugurated in connection with the construction of the Boulder Dam a series of tests on cement mortars to determine the effect of time upon strength, change of volume, and resistance to the action of sulphates. The results of these tests up to the age of ten years are given in a paper by Messrs. R. E. Davis, W. C. Hanna, and E. H. Brown in the Journal of the American Concrete Institute for September, 1946. An interpretation of the results is given in the following.

Properties of the Cement.

The cements used in the tests were produced in a laboratory rotary kiln and were ground in a laboratory batch mill. The range in composition was much wider than that of commercial cements. Omitting isolated extreme values and those of certain specially-constituted cements, the chemical analyses of the clinker from which the cements used in the tests were ground were within the following limiting percentages :

	SiO_2	Al_2O_3	Fe_2O_3	CaO	No. of samples.
First series ..	20·9 to 26·3	3·7 to 7·7	2·1 to 5·5	61·3 to 67·9	20
Second series (fine cements) ..	24·2 to 25·1	4·5 to 5·2	3·9 to 5·5	62·4 to 63·5	7
Third series (heat treatment) ..	23·9 to 26·3	4·0 to 5·8	2·3 to 4·9	62·0 to 66·8	9
Fourth series (fineness)	23·9 to 26·2	4·2 to 5·8	2·7 to 4·8	62·1 to 66·7	12

The magnesia content was low and varied from 2·4 per cent. to 4·0 per cent. ; in one case it was 4·7 per cent. The loss on ignition was also low for all samples and varied from 0·1 per cent. to 0·4 per cent. The free lime content was generally below 0·5 per cent. except in one case where it reached 1·7 per cent.

The initial setting times of all the cements tested by the Vicat apparatus were within the limits of 1¼ hours and 6½ hours. Final setting times were between 4 hours and 9¾ hours. All the cements complied with the A.S.T.M. standard steam test for soundness.

The fineness was recorded as the average of sieve analyses made at four separate laboratories. The amounts passing an American standard 200-mesh sieve (the nominal aperture of which is 0·0030 in. compared with British Standard sieve No. 170 which has a nominal aperture of 0·0035 in.) varied from 79·9 per cent. to 87·4 per cent. for the first series, from 89·4 per cent. to 96·1 per cent. for the second series (that is the fine cements), from 83·2 per cent. to 88·5 per cent. for the heat treatment samples, and from 78·5 per cent. to 95·3 per cent. for the samples for

the fineness tests. The specific surface was determined by a microneter; the corresponding values determined by the Wagner turbidimeter, in accordance with the United States standard specification, were about 17 per cent. higher. The specific surface values, measured in square centimetres per gramme, varied from 1100 to 1240 for the first series, from 1280 to 1730 for the second series, from 1130 to 1270 for the third series, and from 920 to 1550 for the fourth series. Thus, although all the samples complied with the American standard requirement for the fineness of ordinary Portland cement, only three samples (in the second series) complied with the corresponding requirements for rapid-hardening Portland cement, if 17 per cent. is taken as the true factor for converting results obtained by the microneter to the equivalent results obtained by the turbidimeter. It is not possible to compare accurately the fineness of the samples with British standard requirements owing to the difference between a U.S. No. 200 sieve and a B.S. No. 176 sieve. The samples in the first and third series are, however, coarser than required by B.S. No. 12 for ordinary Portland cement. Those in the second and fourth series comply with B.S. No. 12 for ordinary Portland cement but, with possibly one exception in the second series, would not comply with the requirements for rapid-hardening Portland cement.

Tensile and Compressive Strengths.

For the briquettes for the tensile test and for the 2-in. by 4-in. cylinders for the compression test, standard Ottawa sand was used. The briquettes were manufactured and cured up to the age of 28 days in accordance with the standard method (A.S.T.M. No. C77-30) current at the time of making the briquettes. After 28 days, half the number of briquettes and cylinders intended for testing at a later age than 28 days were stored in water at 70 deg. F., the remainder being stored in an open room where they were protected from direct sunlight and rain but subject to daily changes of temperature and humidity. During the maximum storage period of ten years the range of temperature was from 30 deg. F. to 115 deg. F., and the humidity varied from 15 per cent. to 95 per cent. For the first 28 days after manufacture the cylinders were cured in accordance with an earlier provisional standard, A.S.T.M. No. C9-16T. The water-cement ratio by weight was about 0·40 (as in British standards) for most of the briquettes and cylinders, but varied from 0·39 to 0·43.

For each sample of cement, tensile and compression tests were made at ages of 1, 3, 7, and 28 days, 3 months, and 1, 5, and 10 years. Each result recorded was the average of three tests.

At 7 days the tensile strength of about half the briquettes was below the minimum strength of 275 lb. per square inch required by the American standard (compared with 375 lb. per square inch required by B.S. No. 12 for ordinary Portland cement; only one of the averaged results equalled the latter strength). One sixth of the mean results were below 100 lb. per square inch.

At 28 days almost one-third of the briquettes failed to attain the minimum of 350 lb. per square inch required by the American standard. At 3 months, all the tensile tests on specimens cured in water showed an improvement on the

strengths at 28 days, or at least showed no retrogression. The specimens that had the lowest strengths at 28 days attained about double that strength at 3 months. At one year, over 55 per cent. of the briquettes cured in water showed a diminution in strength compared with 3 months, at 5 years 92 per cent. of the averaged results were below those for one year, but at 10 years only 62 per cent. of the results were lower than at five years. Nevertheless, at ten years 46 per cent. of the results were lower than at 28 days, the worst case being 54 per cent. of the strength at 28 days.

In almost all cases the briquettes matured in air after the first 28 days of moist curing had a large increase in tensile strength at the end of ten years, although in a few instances slightly lower strengths were shown at intermediate ages.

The compressive strength of about two-thirds of the cylinders cured in water progressively increased up to one year or five years, and thereafter decreased. In only a few instances was the strength at ten years less than that at 28 days, the maximum reduction being under 5 per cent. For about 78 per cent. of the results the strengths of cylinders matured in air were appreciably higher than those of the corresponding cylinders cured in water, and in no case was a general decline in strength of air-matured cylinders shown with the passage of time. At ten years the compressive strengths of the water-cured cylinders were between 2,370 and 5,880 lb. per square inch, and of air-matured cylinders, between 2,360 and 7,680 lb. per square inch, except for one specimen which attained only 1,910 lb. per square inch. The water-cement ratio of this specimen was 0·39 by weight.

A fair correlation between the age-strength relationship is exhibited by the results of the tensile and compressive tests for each cement, although generally the percentage variations were greater for the tensile strengths than for the compressive.

The probable causes of the foregoing variations in the strengths of the cements are discussed in the following.

Effect of Composition on Strength.

The calculated composition of compounds, computed on the basis of the sum of the percentages of the five principal oxides being 100, are given in the report, the authors of which make certain comments upon which the following observations are based.

There appears to be little difference between the tensile strengths of air-matured briquettes at ten years if the amount of tricalcium-silicate is between 16 per cent. and 55 per cent. For the cements containing no tricalcium-aluminate the highest strength was obtained with a cement having 55 per cent. of tricalcium-silicate ; the analysis of this cement showed 6·2 per cent. of Fe_2O_3, but otherwise the composition was within the limits given for the first series. For cements containing 11 per cent. of tricalcium-aluminate the lowest strength was that of a cement in the first series (with a free lime content of 0·6 per cent.) with 68 per cent. tricalcium-silicate.

For water-cured briquettes containing no tricalcium-aluminate, the strengths at the age of several years did not appear to be influenced greatly by the amount

of tricalcium-silicate, but with 11 per cent. of tricalcium-aluminate such strengths are lowest for the cement already mentioned as having the greatest (68 per cent.) content of tricalcium-silicate.

The retrogression in tensile strength at later ages, as exhibited by all the water-cured specimens in the first series, is considerably greater for cements that have 11 per cent. of tricalcium-aluminate than for cements that have none of this compound. The difference between the tensile strengths of air-matured and water-cured briquettes is in general considerably greater for cements containing 11 per cent. of tricalcium-aluminate than for those without any of the compound.

For water-cured briquettes the tensile strength at 10 years was less than that at 28 days for cements with 6 per cent. or more of tricalcium-aluminate, and less than that at 7 days with more than 11 per cent.

One cement containing 59 per cent. of tricalcium-silicate and 18 per cent. of tricalcium-aluminate gave the highest tensile strength at ten years for air-matured briquettes and the lowest for water-cured briquettes.

The maximum compressive strength at ten years of the air-matured cylinders with cements of the first series containing no tricalcium-aluminate was exhibited by the cement already described as having 55 per cent. of tricalcium-silicate. Higher or lower amounts of the latter compound are accompanied by lower strengths. For cements containing 11 per cent. of tricalcium-aluminate the higher the amount of tricalcium-silicate the higher the compressive strength at ten years. For the specimens cured in water the effect of the amount of tricalcium-silicate on the compressive strength at ten years appeared to be negligible regardless of the amount of tricalcium-aluminate. In general the compressive strengths at the later ages of cements with high tricalcium-silicate content were substantially greater for air-matured than for water-cured cylinders. For cements low in tricalcium-silicate the strengths at later ages were little affected by conditions of storage.

For water-cured cylinders the greater the amount of tricalcium-aluminate within the range of 6 per cent. to 20 per cent. the lower were the strengths at ten years. For air-matured cylinders the strengths at ten years were not affected appreciably by the amount of tricalcium-aluminate for cements of normal composition.

Under both wet and dry conditions of storage the effect of tetracalcium-aluminoferrite was generally to increase the tensile strength, although for water-cured briquettes at later ages the effect of this compound was small. On the other hand, the effect of this compound was substantially to reduce the compressive strength of water-cured cylinders. The same tendency was noticed for air-matured cylinders except that at later ages it appeared that the effect of this compound was to cause a slight increase in strength.

The increase in tensile strength of air-matured briquettes is less affected at all ages by increase in the amount of dicalcium-silicate than by the amount of tricalcium-silicate but for water-cured briquettes the effect of these two compounds is about equal at later ages. The effect of dicalcium-silicate increases at a substantial rate after the age of one year.

Effect of Fineness on Strength.

Each of the three cements in the fourth series was ground to four different degrees of fineness corresponding approximately to 80 per cent., 87 per cent., 92·5 per cent., and 95 per cent. passing a 200-mesh sieve. The cements differed from one another principally in their content of tricalcium-silicate, which was 11 per cent., 31 per cent., and 57 per cent. Regardless of the latter, however, the finer the cement the higher were the tensile strengths of air-matured briquettes, the effect of fineness being much more pronounced for the cements with the low tricalcium-silicate contents. For water-cured briquettes the fineness appeared to have no effect on the tensile strength at ten years, but for air-matured and water-cured cylinders the finer the cement the higher were the compressive strengths at ten years. All cylinders showed an increase in strength between one year and ten years, but the slight retrogression in the case of certain of the water-cured cylinders between five years and ten years was too variable to be related to either fineness or tricalcium-silicate content.

Change of Volume.

The specimens for the tests relating to change of volume were 1½ in. square by 12 in. long and were composed of mortar mixed in the proportions of 1 part of cement to 3¼ parts of Boulder dam sand. The latter all passed a No. 4 sieve and had 3 per cent. finer than a No. 100 sieve. The fineness modulus of the sand was 2·68, and the composition was quartz 63 per cent., limestone 9 per cent., and chalcadony 9 per cent. The water-cement ratio by weight varied from 0·57 to 0·63. For the first 28 days the specimens were cured in a moist atmosphere under conditions of time-temperature variations similar to those in mass concrete construction. After 28 days half of the specimens for each cement were stored continuously in air at 70 deg. F. and at a humidity of 50 per cent. The remaining specimens were stored in water at 70 deg. F.

The changes in lengths of the specimens were measured at various ages up to ten years, and the following is a summary of these observations.

For specimens dried in air, the amount of tricalcium-aluminate had no apparent effect on the shrinkage. Regardless of age, the higher the amount of tricalcium-silicate the lower was the shrinkage, although within the normal range of 25 per cent. to 55 per cent. of tricalcium-silicate the effect of variations in the amount of this compound was small.

The fineness of the cement appeared to have little or no effect upon the shrinkage at any age, nor upon the expansion of the specimens cured continuously in water. In general, with wet curing, the greater the amount of tricalcium-aluminate and the greater the amount of tricalcium-silicate the greater was the expansion.

Resistance to the Action of Sulphates.

For the purpose of the tests for determining the resistance to the action of sulphates, one part each of the briquettes of each cement broken at 28 days was immersed in a 2 per cent. solution of sodium sulphate maintained at a tem-

perature of 70 deg. F. The other part of each briquette was immersed in a 10 per cent. solution. The specimens were observed periodically up to 18 months. The degree of attack was assessed visually.

The specimens in the 10 per cent. solution showed the effect of sulphate attack within four months and most of the specimens in the 2 per cent. solution exhibited signs of disintegration within eight months. Specimens containing cements having over 6 per cent. of tricalcium-aluminate disintegrated rapidly in both solutions. Specimens with below 6 per cent. tricalcium-aluminate showed strong resistance in both solutions throughout the period of the test. The greatest resistance was shown by cements with from 2 per cent. to 4 per cent. of tricalcium-aluminate and a medium or low proportion of tricalcium-silicate.

The fineness of the cement did not appear to be significant in resisting attack.

Conclusion.

The authors of the report, upon which this present article is based, emphasise the limited number of specimens used in the various tests. The conclusions drawn from the tests are merely indicative of trends. The tests were made on mortars and small specimens and, although these trends might be exhibited by small concrete specimens under similar conditions of curing, the application of the results to concrete structures of substantial size would probably not be justified.

New Cement Paints.

A water-paint containing cement is the subject of a recent Canadian patent. The principal constituents are 12 parts of Portland cement, 7 parts of linseed oil, and less than 2 parts of water. The dispersal throughout the solution of a small quantity of magnesium carbonate maintains the cement in suspension.

A recent Belgian patent describes the ingredients of a new cement paint as 50 parts of Portland cement, 1 part of lime, 3 parts of plaster of Paris, 5 parts of casein, 2 parts of fluorspar, and ½ part of sodium silicate. The sodium silicate should be in the form of a powder. The mixture is reduced to the required consistency by adding water.

A distemper is produced, according to a recent Dutch patent, by mixing cement with chalk, casein and anhydrous sodium sulphate.

The Cement Industry Abroad.

UNITED STATES.—We reported in our number for July, 1946, that in February, 1946, the cement industry in the United States was producing at the rate of about 50 per cent. of its total capacity. This rate, however, was almost double that for February, 1945 (about 29 per cent.), and the improvement has been continued. The United States Bureau of Mines states that the industry operated at 73 per cent. of its capacity in June, 1946, in which month the total production was about 14½ million barrels, which is approximately equal to the total deliveries for that month. This quantity, which is 62 per cent. greater than the production in June, 1945, includes the small production in Puerto Rico and Hawaii. In Hawaii a cement works was put into operation in 1945. In the twelve months ending in June, 1946, the total production in the United States exceeded 150,000,000 barrels, the average ratio of production to capacity being over 50 per cent.

According to an article in " Concrete " for September, 1946, clinker production in the United States was 72 per cent. greater in June, 1946, than in June, 1945, and the increase in the amount of fuel consumed is given as 79 per cent. of coal, 31 per cent. of oil, and 54 per cent. of natural gas.

FRANCE.—In " Travaux " for September, 1946, M. H. Hupner describes the development of the cement industry in France. In 1920 the capacity of the industry was about 2,000,000 tons, but it had reached more than 7,000,000 tons in 1930 and more than 8,000,000 tons in 1934. The production in 1938 exceeded 3,300,000 tons. At present there are 54 cement works in operation in France. Four works are inoperative due to war damage, but three others are in course of erection. These figures include works producing Portland and high-alumina cement.

Since the war the production of cement has increased considerably. In December, 1944, the monthly production was less than 25,000 tons, but had increased to about 125,000 tons per month in the spring and summer of 1945, and to 170,000 tons by December, 1945. The latter quantity also represents the average monthly production for the first quarter of 1946, but thereafter successive increases resulted in the production of over 300,000 tons per month in July, 1946, compared with a monthly average of 275,000 tons in 1938. The total production for the first six months of 1946 was 1,370,000 tons and the amount of coal consumed was about 400,000 tons. These figures include all types of cement, for example, ordinary and rapid-hardening Portland cement, metallurgical cements, high-alumina cement, white cement, etc.

ITALY.—There are more than one hundred cement works in Italy, the potential capacity of which is about 6,000,000 tons annually. Many of these works, however, were damaged during the war and among them are some of the most modern plants having the greatest productive capacity. The amount of cement required for reconstruction work in Italy is estimated at 9,000,000 tons, which would be consumed over a period of seven years. To this quantity must be

added the normal annual consumption for other purposes, which before the war was about 4,000,000 tons. Shortage of fuel and lack of new machinery are the major obstacles to the rehabilitation of the Italian cement industry.

PORTUGAL.—The cement industry in Portugal is characterised by the many schemes in hand for the expansion and improvement of existing works. In a works at Alhandra an additional rotary kiln, grinding plant, and coal drying plant, capable of an annual production of 60,000 tons, are being installed. At Maceira a plant with a capacity of 100,000 tons annually is being erected. These and other smaller installations are expected to be in operation by the end of 1947.

ARGENTINE.—The cement consumed in the Argentine before the war was partly produced in that country and partly imported. During the war, imports almost ceased and a small amount was exported. According to statistics published by the Argentine Government, the production in 1927 was about 200,000 tons and about 400,000 tons were imported. By 1937 production had risen to more than one million tons annually, while imports were less than 100,000 tons. In 1942 imports practically ceased, Argentine production was over one million tons, and about 100,000 tons were exported. The latest year for which figures are available is 1944, when the production was nearly 1,100,000 tons.

BRAZIL.—There are four cement works in Brazil having a combined capacity of three-quarters of a million tons annually. Since the annual production, according to Brazilian Government statistics, is about equal to this amount, the Brazilian works are apparently producing cement at their maximum capacity. New plant is being installed in two of the works, and when in operation the total capacity will be increased to about 880,000 tons annually.

The foregoing notes on the cement industry in Italy, Portugal, Argentine, and Brazil are abstracted from "Cemento-Hormigon" for September, 1946, and from the number for November, 1946, the following statistics relating to Spain have been taken.

SPAIN.—The total amount of Portland cement clinker produced in the first nine months of 1946 was nearly 1,300,000 tons, which is an increase of over 18 per cent. on the production in the corresponding period of 1945. The total sale of Portland cement in the same period in 1946 was 1,240,000 tons, being 12 per cent. higher than in 1945. The sale of special cements exceeded 100,000 tons in the first nine months of 1946 which is an advance of about 16½ per cent. on the same period of 1945.

BELGIUM.—According to an article in "Verre et Silicates Industriels," November-December, 1946, the total production of cement in Belgium in 1945 was a little over 640,000 tons, but in the first six months of 1946 the production exceeded 890,000 tons. In February, 1946, there were 17 cement kilns in operation in Belgium; this number had increased to 25 by July, 1946.

New Standard Specification for Portland Cement in Eire.

In October, 1946, the Building Research Committee of Eire published a standard specification for Portland cement, which is a revision of, and apparently supersedes, the standard specification for Portland cement issued in 1938 by the Institution of Civil Engineers of Ireland. In general, the new standard conforms to British Standard No. 12 (1940) and relates to ordinary and rapid hardening Portland cements. There are, however, the following differences between the Irish and British standards ; the corresponding requirements of the latter are given in brackets.

The total loss on ignition must not exceed 4 per cent. (the limits in B.S. No. 12 are 3 per cent. for temperate climates and 4 per cent. for tropical climates). The expansion as determined by the Le Chatalier method must not exceed 5 mm. (10 mm.) ; if this limit is exceeded the expansion after seven days æration must not exceed 2·5 mm. (5 mm.). For æration the cement must be spread out to a depth of 70 mm. (76·2 mm.),

The spatula used when making briquettes must not exceed 350 gm. (340 gm.) in weight. Although the standard is an Irish specification, the standard sand for making briquettes is specified as Leighton-Buzzard sand. The tensile strength is deemed to be the average result of tests on four (six) briquettes. For ordinary Portland cement the ultimate tensile stress at three days must be not less than 330 lb. (300 lb.) per square inch, and at seven days not less than 430 lb. (375 lb.) per square inch. For rapid-hardening Portland cement the average ultimate tensile stress must be not less than 300 lb. per sq. inch at one day (the same as B.S. No. 12), and not less than 455 lb. (450 lb.) per square inch at three days. The optional compression test in the British standard is not specified.

One sample of cement for testing must be taken from each 100 tons (250 tons) or part thereof, the sample being made up of five (twelve) equal portions taken from separate bags or from different positions in the heap or heaps of the cement. The amount of cement to be gauged for use with the Vicat apparatus must be 500 grammes ; there is no corresponding requirement in B.S. No. 12. The trowel used therewith must weigh about 200 gm. (213 gm.).

Other requirements that are not given in B.S. No. 12 include the following. During the setting test and during the first 24 hours of the storage of briquettes the relative humidity of the storage chamber must be 90 per cent. The cement must be stored on the site or elsewhere in a suitable weathertight building in such a manner as to permit access for inspection and identification. On the other hand, delivery in containers, other than paper bags containing 112 lb. of cement, is not covered by the Irish standard.

Among minor differences is that the issue of B.S. No. 410 referred to for test sieves is that of 1943 instead of 1931 as in B.S. No. 12. What is termed ordinary Portland cement, as opposed to rapid-hardening Portland cement, in the British standard is termed " normal " Portland cement in the Irish standard.

The Physical Nature of Particles of Lime.

AT the annual convention of the National Lime Association of the United States, held in 1946, Mr. H. R. Staley contributed a paper containing quantitative information regarding the physical characteristics of particles of lime. This information was based upon research by the use of new methods and apparatus such as the nitrogen adsorption surface area apparatus, the electron microscope, and differential thermal analysis.

The nitrogen adsorption apparatus enables external surface area and internal pore-surface to be measured, although for the smaller pores only qualitative results are obtainable. Soft-burned quicklimes have a surface area up to 1·3 sq. m. per gr. compared with a maximum surface area of 0·45 sq. m. per gr. for hard-burned lime from the same limestone. Soft-burned lime is more porous than hard-burned, most pores in the former being 30 Å on the average, with some pores as small as 7 Å. No pore in the hard-burned lime was smaller than 45 Å.

Hydration of soft-burned limes with the minimum of water produced hydrates having a surface area of 22 sq. m. per gr. ; from hard-burned limes the mean surface area of the hydrates was 15·5 sq. m. per gr. Hydration with four times the minimum amount of water gave, however, surface areas of 22·5 sq. m. per gr. and 32·2 sq. m. per gr. for soft-burned and hard-burned lime respectively.

Increase in temperature of wet hydration caused a reduction in the surface area. A similar result was obtained with an increase in the amount of water in excess of the minimum required for hydration. Slaking by air and hydration by steam produced hydrates with surface areas as low as 10·4 sq. m. per gr. and 8 sq. m. per gr. for soft-burned and hard-burned limes respectively.

By burning limestone with 0·5 per cent. of sodium chloride a lime of low surface area and hydrates with slightly lower surface areas were produced.

These notes are taken from "Building Science Abstracts," May, 1946.